Summary of the Final Report of Research Results

1) Title of the proposed research

Southern Hemisphere validation of GOSAT XCO_2 and XCH_4 from TCCON solar FTS measurements in Australia and New Zealand

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4) Summary of the Final Report of Research Results

GOSAT carbon dioxide and methane retrieval errors need to be well characterized if these data are to be used to constrain inverse model surface flux estimates. Data from the Total Carbon Column Observing Network (TCCON) are the primary validation data for GOSAT Short-Wavelength InfraRed (SWIR) retrievals. However, systematic retrieval errors and uncertainties in calibration must be accounted for to make best use of the TCCON data for GOSAT validation. Low inherent atmospheric variability of CO_2 and CH_4 in the southern hemisphere (SH), combined with the latitude range spanned by SH TCCON sites (12° S – 45° S), provides unique (but not exhaustive) conditions to validate GOSAT SWIR retrievals and characterise systematic retrieval biases which, if uncorrected, would lead to spurious surface flux estimates. The goals of the project were:

- to characterize XCO_2 and XCH_4 variability in the Southern Hemisphere and identify and minimise TCCON instrumental artifacts and retrieval biases;
- to apply the high quality, self-consistent SH TCCON timeseries thus generated to validate NIES GOSAT SWIR L2 retrieval products (XCO_2 and XCH_4); and
- to understand the geophysical drivers of observed variability using tagged tracer modelling, and hence characterise the representativity of SH (Australasian) TCCON measurements for satellite validation and a posteriori correction of satellite retrieval biases.

The project also sought to open an effective means of communication between the SH TCCON PI's and the NIES GOSAT retrieval team, so that advances in understanding of TCCON data error characteristics could be rapidly taken up for GOSAT validation.

Over the past five years we have performed a critical appraisal of measurements from the three Southern Hemisphere (SH) TCCON sites, Darwin and Wollongong (Australia) and Lauder (New Zealand), in order to generate a high quality, self consistent data set for GOSAT validation. Thanks to activity within this project and network-wide, our understanding of TCCON error budget and inter-station consistency has evolved markedly over the duration of the RA project. At the close of this project we are entering a new era for TCCON. The precision and accuracy of satellite retrieval algorithms has progessed to the point where TCCON inter-station consistency should ideally be characterised at the 0.05% level for XCO_2 [Buchwitz et al., 2012]. Careful intercomparison and characterisation of the consistency of the Southern Hemisphere sub-network remains as important and challenging as ever, and will one objective of a future RA project.

Screened and calibrated SH TCCON data have been compared with NIES GOSAT v01.xx and v02.xx retrievals. NIES GOSAT retrieval error characteristics have been evaluated using both the comparison of co-located GOSAT and TCCON retrievals and the statistical analysis of GOSAT retrievals over Australasian land masses. Comparison of v02.xx retrievals with co-located TCCON measurements in Australia and New Zealand show a substantial reduction in retrieval bias and variability compared to the v01.xx retrievals. The standard deviation of v02.xx differences with SH TCCON are 1-2 ppm (0.5%) for XCO_2 and 10-20 ppb (0.5-1%) for XCH_4. The erroneously skewed distributions of XCO_2 and XCH_4 in the austral spring and summer which characterised the v01.xx retrievals are absent in the v02.xx L2 products.

We have assessed the consistency between the XCO_2 timeseries at SH TCCON sites and the CarbonTracker CT2011 oi CO_2 analysis [Deutscher et al., 2013]. While agreement between the model analyses and the TCCON timeseries is generally good, significant differences between model analyses and TCCON observations are found at times, particularly at Darwin, which we do not believe are due to instrument errors. The observed intra-seasonal variability of XCO_2 and XCH_4 at Wollongong is greater than that observed at either Darwin or Lauder. It is also greater than XCO_2 variability in CarbonTracker analyses.

Differences between the model simulations and the observations have been interpreted using tagged tracer modelling. Sensitivity of model-observation mismatch to the prescribed fluxes and transport has been evaluated by considering multiple terrestrial biosphere flux models (CASA and SiB) and multiple transport models (TM3, TM5 and GEOS-Chem). The Darwin XCO timeseries has been used to evaluate the timing and magnitude of modelled biosphere burning contributions to observed XCO_2 variability. Based on these analyses we conclude that large eposodic differences between model and observed XCO_2 at Darwin are most likely due to errors in the analysed terrestrial biosphere fluxes for the Australian Northern Territory region.

5) List of publications relating to the proposed research

N. Deutscher, V. Sherlock, S. Mikaloff-Fletcher, D.W.T. Griffith, J. Notholt, R. Macatangay, B.J. Connor, J. Robinson, H . Shiona, V.A. Velazco, P.O. Wennberg, and D. Wunch. Drivers of XCO_2 variability at southern hemisphere Total Carbon Column Observing Network sites. *Atmos. Chem. Phys. Discuss.*, 13:14331–14376, 2013. doi: 10.5194/acpd-13-14331-2013.
(Accepted for publication in ACP)

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F. Hase, B. J. Drouin, C. M. Roehl, G. C. Toon, P. O. Wennberg, D. Wunch, T. Blumenstock, F. Desmet, D. G. Feist, P. Heikkinen, M. De Mazière, M. Rettinger, J. Robinson, M. Schneider, V. Sherlock, R. Sussmann, Y. Té, T. Warneke, and C. Weinzierl. Calibration of sealed HCl cells used for TCCON instrumental line shape monitoring. *Atm. Meas. Tech.*, 6(12):3527–3537, 2013. doi: 10.5194/amt-6-3527-2013. URL http://www.atmos-meas-tech.net/6/3527/2013/.

Y. Yoshida, N. Kikuchi, I. Morino, O. Uchino, S. Oshchepkov, A. Bril, T. Saeki, N. Schutgens, G.C. Toon, D. Wunch, C.M. Roehl, P.O. Wennberg, D.W.T. Griffith, N.M. Deutscher, T. Warneke, J. Notholt, J. Robinson, V. Sherlock, B. Connor, M. Rettinger, R. Sussman, P. Ahonen, P. Heikkinen, E. Kyro, and T. Yokota. Improvement of the retrieval algorithm for GOSAT SWIR XCO_2 and XCH_4 and their validation using TCCON data, *Atmos. Meas. Tech*, 6(6), 1533–1547, 2013.

I. Morino, O. Uchino, M. Inoue, Y. Yoshida, T. Yokota, P.O. Wennberg, G. C. Toon, D. Wunch, C.M. Roehl, J. Notholt, T. Warneke, J. Messerschmidt, D.W.T. Griffith, N.M. Deutscher, V. Sherlock, B. Connor, J. Robinson, R. Sussmann, and M. Rettinger. Preliminary validation of column-averaged volume mixing ratios of carbon dioxide and methane retrieved from GOSAT short-wavelength infrared spectra. *Atmos. Meas. Tech.*, 4:1061–1076, 2011.